GAS ENGINE FOUNDATIONS

BY

O. H. HAENSSGEN

AND

H. M. NICHOLLS

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GAS ENGINE FOUNDATIONS.

O. H. HAENSSGEN.

Too often but little attention is paid to those parts of the gas engine that, in a strict sense, do not contribute to its operation. The average designer and manufacturer considers his work done when the engine, after having run satisfactorily on the test stand, has been shipped. Of course the buyer is supplied with an erecting and foundation plan that shows in a general way how the engine is to be placed in the engine room, how the foundation must be built, and the arrangement of the various accessories and the piping. The plan applies to ideal conditions only, it must often be modified considerably to meet the special conditions of the place. Just here may arise questions that are very intricate and call for much good judgment, experience and engineering skill. The solution of such problems is left to the buyer. Now, having no special knowledge of the engine and its requirement, he has to depend upon the advice of some friend of his or the kind hints of the gas engine salesman. if he happens to be about. The result of these groping efforts is an engine plant that sometimes is satisfactory, but in many cases is not. True, there are no serious defects visible, and for a while everything may go well. But by and by little troubles appear and worry the operator by their persistency in reappearing in spite of his greatest care.

Some pipe joint gets leaky, or a certain nut shows a special desire to travel off its bolt, or one of the main bearings cannot be kept cool, or a belt slips and runs off the pulley, or, in short, about anything possible, or rather impossible, happens just at an improper moment. A feeling of unsafety and doubtfulness creeps into the operator's mind and soon he loses all confidence in his engine.

This condition of affairs is disagreeable and dangerous for both the owner and the manufacturer of the engine. The former complains about his mysterious troubles and the latter does not know how to remedy them. Correspondence on the subject is generally of no avail, owing to the difficulty of obtaining a correct description of the disease, and the last expedient, sending an expert, is very costly for him who is obliged to pay. But the expert even may see the symptoms only and by trying to cure them offers only temporary relief. The causes remain still hidden and yet active to work mischief again. To discover them is very difficult.

as at least some of them are buried beneath the floor of the engine room.

If repeated and close investigations of the whole plant show that the engine proper is in good working condition and its accessories are in accordance with the acknowledged rules, some feature of the general arrangement or the installation must be suspected. In such mysterious cases it is a good plan to direct one's suspicions soon to the engine foundation. The fault may be in its location, in the design, in the method of construction and the materials used. A failure in one of these points can scarcely be remedied except at a great expense and loss, by doing the work wholly or partly over again. Of course, this expedient is resorted to reluctantly and in quite severe cases. Usually, however, the plant is left just as it is and thus forms a constant source of worry to its owner. The purpose of the present discussion is to go somewhat into the details about gas engine foundations, especially of small and medium-sized engines.

The location of the foundation in the engine room depends to a large extent upon the special conditions of the case. If the engine is to replace another source of power, its position is generally fixed pretty close by the existing line shaft or the pulley of the driven machine, as their centerlines must be parallel to the shaft of the engine. The same applies to new installations in so far as the driven machinery is set according to the requirements of their operation and the engine must in turn be set to suit them. Often the size and shape of the engine room, or the possibility of obtaining an easy way for the exhaust pipe suggests a suitable place for the engine.

Good accessibility to all parts of the engine is the principal consideration and if possible an ample passage all around should be provided. Then only will the engine receive proper care and can easily be kept in good order. In case of an emergency the operator need not perform acrobatic feats and endanger his body in order to make some repairs or adjustment. Not only should he be able just to feel some part of the engine he wants to inspect, but also must he see it plainly, in order to ascertain its condition thoroughly. In horizontal engines the igniter flange and mechanism, as well as the valve motions require special attention, consequently that end of the engine should be about two or three feet away from the wall. This will also be very advantageous if the cylinder cover must be removed for some reason, for instance, to replace a broken gasket or to clean the water jacket thoroughly, or even to drive out a stuck piston. If between the end of the crank shaft or the rim of the main pulley and the wall sufficient space is left to exchange the pulley, or to dismount the flywheel without lifting the shaft out of its bearings, much trouble and hard work may be saved.

If the engine must be started by turning the flywheel over by hand, a clearance of at least 40 inches should be allowed in front of the rim of the wheel. If a starting crank is used a similar space should be left about the starting end of the shaft.

In vertical engines of the modern type, having the cylinder above the shaft. the space about the motor may often be reduced somewhat, as the most sensitive parts, the valves and the igniter, are placed on top and thus readily accessible.

Engines of this kind, especially those of the two-cycle type, have their crank shaft and connecting rod hidden within the crank case. Often quite a lot of patient work must be done if, for instance. the connecting rod head and the center bearing of the shaft are to be inspected. As the shaft lies pretty low, the work necessitates a stooping or kneeling position which in itself is very uncomfortable. Some failure of the lubrication may call for such a job, and it is advisable to provide a space of at least 30 inches on both sides of the crank case in order to render operations not too difficult.

In laying out the engine foundation, a few hours spent in drafting work will save many disappointments and useless expenses. First a plan of the engine room is drawn on a rather large scale, the doors and windows must be marked; any obstacles, as posts, staircases, pipes and the like that might in any way interfere with the new machinery, must also be drawn in exactly. The location of the water supply pipe, also of the sewer, or other means to lead away the waste water must be considered. A suitable place must be found where the exhaust pipe may be let out, with the least amount of annoyance to the neighborhood and in the simplest and cheapest way. These points are best studied right on the premises by an experienced man, as often the relative position of the neighboring buildings and their height is of considerable bearing. The author might mention the difficulties caused in closely built towns by the noise and the smell of the exhaust, or by the vibrations of an engine plant being transmitted to some adjoining building. All information gained about the future abode of the engine should be utilized carefully to complete the erecting plan. Next, outline plan views of the engine and the driven machinery are sketched in the same scale on tracing paper. These transparent sketches may be moved about till the best place for each of them is found. Here they are fastened and then the various pipes and the power transmitting gear are easily put down.

Till now the foundation has been considered as a part of the machinery, but it must also be looked at as an architectural structure and in its relation to the building containing it.

The foundation serves not only to connect the engine to the premises, in order to prevent it from following the belt pull, but also to take up the various free forces produced by the power-generating movements of the engine. These very forces, though often very small, are apt to do much harm by their constant repetition. if they are not properly harnessed.

Every gas engine, by the movements of the reciprocating parts, produces more or less violent vibrations that of course are transferred to the foundation. The heavier the foundation block is, the more resistance it will certainly offer to the vibrations by its inertia. It will reduce them, but cannot suppress them wholly. The building material being but little elastic, each vibratory wave is carried right through the block and from its surfaces transferred to the adjoining bodies. Thus if the foundation block is directly and rigidly connected to other parts of the building, either to its side walls by the floor covering, or by its position on the vaults of the cellar, the vibrations travel along the masonry and are felt over a large area. The vertical walls partake of the trembling and in the top stories the shaking aggravates. The noises of the engine are also increased and multiplied by the resounding action of the large vibrating surfaces that swing in strict accordance to the motions of the piston.

The effect on the building is naturally rather slow and varies considerably with the intensity of the vibrations and the condition of the masonry. Sometimes it shows only after many years of operation. Consequently it is of great importance to him who is going to buy a gas engine to remove the primary cause by selecting an engine that is practically vibrationless, and to have what little is left of vibrations rendered harmless by a correct foundation.

The foundation block should stand separately and without rigid connection to the neighboring masonry. Its weight alone should give the engine a solid foothold, and the surrounding soil should not be relied upon to hold the block in place. On the contrary, the soil should be filled in about the block as loosely as possible, or better still, an air space might be left. In this fashion the transmission of vibrations and sounds is reduced very much.

In some measure the conditions of the soil must also be looked into before the place for the foundation is selected. In small plants this is not an important question and it is generally solved when the walls of the engine room are built. If the soil is capable of carrying these walls safely it will most likely also suffice for the foundation. If necessary the soil may be fastened artificially at a comparatively small expense.

One point, however, should not be overlooked: the foundation must be erected in a dry place; wet soil transmits vibrations and noises about just as well as water alone and is entirely unfit. The author has been told of a gas engine plant located in the vicinity of a river. The foundation had been placed upon the water-soaked ground without any proper precautions. The vibrations were easily perceptible across the bed of the river as far as 450 yards distant. They were so disagreeable in the fine residences along the river that the plant had to be put out of operation. Two mistakes had been made in this case, the foundation had been erected directly on a swamp-like soil and the block was about as high as long, and thus of little stability. If similar conditions are met, it is much better to choose another and more favorable place, if it can be done by any means. In spite of the very costly and artificial devices often used to fasten the unsolid soil, the results are often unsafe.

Before an engine foundation for a special case is designed and dimensioned, the material to be used must be decided upon. Practically only three kinds enter in competition: Single stone blocks, hard baked bricks or similar elements and concrete. Which of them is chosen depends partly upon the preference of the owner, partly on the local price.

Solid stone blocks are expensive, even when the crude material can be had cheaply, owing to the difficult finishing process. Generally only the softer kinds of stone are used, as they are easier to work. Though a well finished stone block makes quite a good looking and suitable foundation, its use is limited to comparatively small engines, especially to the vertical types.

Hard baked bricks require a good

strong mortar composed of one part of Portland cement and from two to three parts of sharp rough quartz sand. The latter must also be free from dust, loam or clay, sifted and thoroughly washed. If the foundation must withstand considerable strains the mortar should be made somewhat richer. a ratio of one part of cement and one part of sand being right. The same mixture may be used for the finish of the top face. The bricks are laid in the same fashion as in high grade architectural masonry. A foundation built in this manner looks very well and is very durable. In the central parts of the block some cheaper brand of bricks or "bats" may be used if they are kept perfectly dry. If natural stones finished squarely are used instead of bricks the richer mixture of mortar must also be applied.

Concrete is the ideal material for foundations. Its properties and advantages have been set forth so completely and enthusiastically by Mr. Nicholls in the article accompanying this, that in order to avoid repetitions the reader is referred to the pages following page 45.

Only a few remarks may be added here, especially about the foundation bolts. Sometimes the thread of a bolt is stripped or damaged otherwise, or the bolt breaks. Of course such accidents may be avoided, but nevertheless they happen and are very disagreeable. The heavy engine frame should be lowered on the foundation slowly and with the utmost care, and the bolts watched and guided into their holes by some attendants. The material for the bolts should be of a good quality and the heads well welded.

But as the erection of an engine must be done often enough under difficult circumstances, in close quarters, and with insufficient help and appliances, mishaps cannot be excluded altogether. As far as the bolts are concerned it proves of great benefit to make them removable. Bolts of this description are frequently used in large steam engine foundations, when the sides of the block are accessible. For each bolt a recess is left in the side of the block which contains a heavy cast iron washer. The bolt is fastened in the hub of this washer by a key. When the latter is withdrawn the bolt becomes loose and may be pulled out at the top.

But the bolts may be made removable in a simpler manner, that is well adapted to the requirements of gas engine practice. This method will be described here with reference to the accompanying sketches. A few dimensions are given in

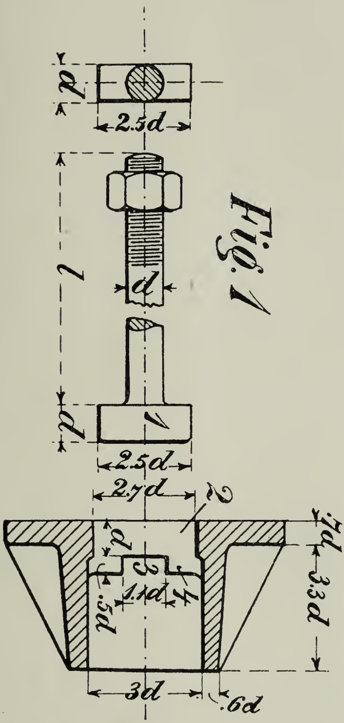
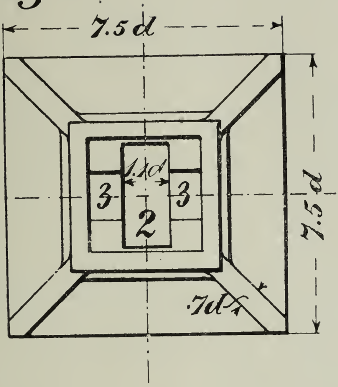


Fig. 1

their ratio to the diameter (d) of the bolt. Fig. 1 shows the bolt which possesses an oblong head (1). The head must be welded carefully to the shank of the bolt; if forged nicely it requires no more finishing. Fig. 2 illustrates the general design of the counterplate belonging to the bolt in Fig. 1. It will be noted that this plate has in its middle an oblong hole 2 corresponding to the bolt head 1, but slightly larger all around. The lower portion of the plate is of the special shape clearly shown in the bottom view. When the bolt is introduced through the hole 2 and turned by 90 degrees, the head engages the two notches 3. If now the bolt is pulled up again it is firmly held in place. The two projections 4 guide the bolt-head into the notches when a quarter of a turn has been made. When the bolt is lowered somewhat it disengages the notches and after turning it to the left a little it may be pulled out easily. The square plate has a good grip on the masonry and this is improved by the ribs at the corners.

If the bolts are arranged in pairs, double counterplates, as drawn in Fig. 3, may be used advantageously, as they give the correct distance of the bolts and are easier to handle. In small foundations it is even advisable to have a single casting for all the bolts.

Fig. 2.



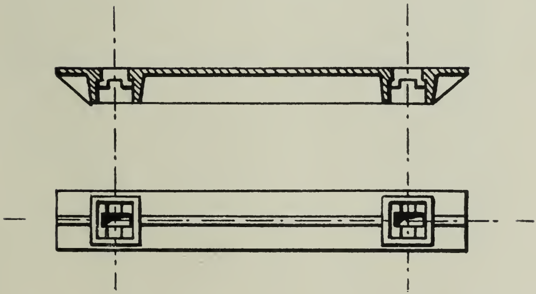


FIGURE 3.

A vertical section through a foundation, showing the arrangement of the metal parts, is represented by Fig 4. The holes 6 are made either round or square and large enough to allow the easy passage of the bolt head. They are moulded in the usual manner about a smooth piece of timber pointed so as to fit the oblong hole in the concrete plate. At the top these timbers are held in position by some laths nailed to the form for the concrete blocks. Below each bolt a recess 5 is left, into which the bolt may be sunk so as to be entirely out of the way. A piece of soft wire tied to the thread serves to pull it up again.

As the foundation is smooth at the top, the engine is easily set, and may even be moved sideways without touching the bolts at all. The wires attached to them are threaded through the holes of the engine base. The engine is now leveled carefully. the bolts are pulled up one by one, turned to fit the notches of the plate and the nuts put on. If now the engine were grouted in the usual manner, the holes 5 about the bolts would fill and the principal advantage of the design would be lost. That is to say, the bolts would then be fixed rigidly and could not be removed except by crude force and by demolishing the block. If, however, the

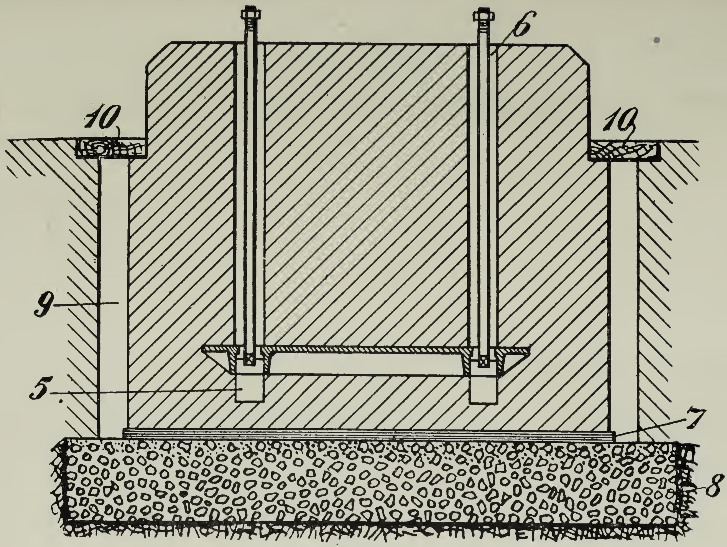


FIG. 4.

grout is prevented from filling, the holes 5, the problem is solved. It is not a difficult task and may be accomplished in several ways. Some waste, rags or wood shavings are stuffed pretty tightly about the top end of each bolt and pressed down about an inch below the surface of the foundation. Thus the bolt is held in position elastically and the cement cannot flow into the holes 6. It forms only a thin layer that may be broken easily without any other damage if a bolt is to be removed.

Now the author knows that this is different from the idea of Mr. Nicholls, who wants a good bond between the bolt and the concrete. This would be a good condition if anything like accuracy could be secured, so that the position of the bolt, once fixed, is no more changed by tightening the nut. Generally this accuracy is lacking, either the holes in the engine frame are spaced inexactly, owing to the shrinkage of the casting and being cored instead of drilled, or the surface of the lugs at the frame is not quite level. Or the whole frame may be set somewhat out of the original center lines for various reasons. Of course the bolt. when being tightened, tends to travel to a position vertical to the top face of the lug. If the bolt is held tightly in the concrete for about one-third of its length it cannot follow the direct line of pull and must bend. The nut rests unequally upon the lug, the thread is squeezed and the concrete crushed sideways. As the nut has no solid hold on its seat it works loose easily and must be tightened time and again. The thread is soon ruined and the bolt rendered useless. If, however, the bolt is left free for all its length, it will adjust itself to the direction of the pull and bending strains are avoided. Thus the engine is safely held in place, each nut has a good bearing, the concrete has to withstand compression stresses only. It must be remembered that the engine is secured to the foundation practically only by the friction existing between the bottom of the frame and the concrete. This friction is obtained by the pressure of the bolts and by the weight of the engine. The shearing resistance of the bolts is of no account, it should not be called upon at all. In consequence the bolts need not be fixed rigidly in a lateral sense, it suffices to hook them to their counterplate as shown.

The method explained here has many good points and is used with full success in a great number of high-grade engine plants. Of course many other devices that give equal satisfaction are applied.

All of them must comply with certain rules or trouble will ensue.

The number and size of the foundation bolts depends principally on the shape ot the engine frame and the power of the engine.

No less than four bolts are used. The bolts must be put as near as possible to those points of the frame where the forces are active; that is, close to the power cylinder and the main bearings. In vertical engines the bolts are easily arranged symmetrically to the center line of the cylinder owing to the simple vertical effect of the explosive force. In horizontal engines the bolts are generally placed right in front of each main bearing and to each side of the cylinder. Sometimes one or two bolts are also put in the center line of the frame.

The diameter of the bolts is not a matter of much calculation, it is found by practical experience. Usually the bolts are not made less than ⅝″. For engines up to 5″ bore they may be ⅝″ to ¾″ diameter; for a bore of from 7″ to 8″—⅞″; will suffice, and for a bore of 9″ or 10″ a bolt of 1″ diameter will be right. For larger sizes of motors the following simple formula gives good results:

$$d = 1 + \frac{D}{40}$$

wherein d denotes the diameter of the bolt, D is the bore of the cylinder, both in inches. The length of the bolt, that is. the part imbedded in the masonry should be l=4 D or 5 D.

The head of the bolt, generally square or oblong, should have about twice the area of the shank, its height may be taken equal to the diameter d. However, the shape of the bolt-head be made, it should be symmetrical in order to avoid bending strains. For this reason bolts with a bend to one side cannot be recommended. The bend prevents turning, but by the pull of the nut it will try to stretch out again, and owing to its small surface the concrete will be crushed and the bolt pulled out partly.

Short bolts are uneconomical as they do not well utilize the weight of the foundation. That part of the concrete lying below the counterplates causes considerable strains on the upper part of the block. Each bolt should be provided with a large washer or counterplate. The face of the plate serves to distribute the pressure of the bolt on a large surface. As the concrete stands a pressure of about 125 pounds per square inch while some 8,000 pounds may be allowed for the wrought iron bolt per square inch of its area, the surface of the washer should be about 65 times larger than the area of the bolt.

The bolt as well as the washer must be prevented from turning. A suitable recess in the washer will hold the square or oblong head of the bolt, the washer proper should have ribs that engage the concrete. Bolts with loops at the end may be allowed in small foundations. An iron bar put through the loops of two neighboring bolts keeps them from turning. Better is a piece of gas pipe that offers a larger surface and does not cut the concrete so easily when the nuts are tightened.

The design of the foundation block generally offers no special difficulties. The top face corresponds to the bottom of the engine frame. Of course it cannot follow all the curves of the cast iron, but a simple rectangular or square surface with a margin of between 3 and 5 inches is laid out. The edges of this face are often bevelled.

In brick foundations at least the width of one brick should be allowed outside of the bolt hole; in concrete work there should be at least a distance of 6 inches from the center of the bolt to the edge of the block.

The height of the block above the floor depends on the design of the engine and on practical requirements. It should be made as small as possible in order to reduce the leverage of the vibratory forces and to lower the center of gravity. In small engines that are started by hand, 30 or 40 inches is about the proper height for the center of the crank shaft above the floor. The bottom of the foundation should be below the frost line, about 40 inches below the floor. On the other hand it must remain about 24 inches above the highest water level. If these dimensions conflict, only a careful study of the conditions may suggest a solution of the problem. Sometimes the water level can be lowered sufficiently either by drainage or by building a well and draining the water off continually. Or a water proof box of sheet iron, concrete or masonry is sunk through the water-carrying earth onto an impervious layer. Upon the latter the foundation is built in the usual way. Of course the joints between the walls of the box and its bottom must also be perfectly water-proof.

Frost alone does not damage a perfectly dry foundation but in combination with moisture its action is destructive. The water enters the pores and little cracks of the masonry. When freezing up, each little drop expands with great force and presses against the walls that confine it. New cracks are thus started and the old ones widened. The material is crushed and larger spaces opened. In these again the water enters and the next frost works its destruction on a larger scale. By the repetition of this process the foundation is gradually torn apart and a total break-down is the last result.

Water alone does neither hurt nor impair the strength and stability of the foundation if the proper materials have been used. How disagreeable the presence of water is with reference to the transmission of vibration and noises has been explained before.

The foundation is not, or at least should not be a working part, but it should perform its duties by remaining immovable by its inertia and by its weight.

The weight of the foundation is calculated from the dimensions of the engine. The total weight of the latter, the weights of its moving parts, the pressures as shown by the indicator card, the number of revolutions, enter into the calculation, and unless all these points are known, no exact figures can be developed. The course of the calculation is rather complicated and laborious and thus only of scientific interest.

For practical purposes, simple formulas will serve quite as well. They have been figured from the average of many successful gas engine plants and are acknowledged to give good results. In these formulas only the style of the engine and its brake horsepower are considered. The latter figure is generally known or can easily be obtained. Thus there is no difficulty at all in using them.

In order to simplify the process still more, the formulas do not give the weight but the cubical contents of the foundation block, based on an average weight of 125 pounds per cubic foot of masonry. The dimensions thus obtained are very liberal and the slight differences in the specific weights of the various building materials may be neglected.

If C stands for the volume of the foundation in cubic feet, and F denotes the force of the engine in brake horsepower, in the horizontal, single acting, four cycle motor, $C = 14F$; in the vertical, single acting, four cycle motor, $C = 7F$; in the horizontal, double acting, four cycle motor; $C = 11F$; in the vertical, double acting, four cycle motor, $C = 5.5F$. In two-cycle motors about 60 per cent more power is generated for an equal cylinder capacity. the cylinder diameter is smaller, the moving masses are of less weight, the pressures are smaller and more evenly distributed. In consequence for the same horsepower, a comparatively smaller foundation will suffice.

For the horizontal, single-acting, two-cycle motor, C=8F; for the vertical, single-acting, two-cycle motor, C=4F; for the horizontal, double-acting, two-cycle motor, C=6F, and for the vertical double-acting, two-cycle motor C=3F.

The figures obtained by these formulas apply to engines of regular design only, having maximum explosion pressures not higher than about 420 pounds, a piston speed not exceeding 700 feet per minute, well proportioned and well balanced reciprocating parts and a rigid frame. For extraordinary conditions special allowances must be made. High pressure motors, as the "Diesel" motor, for instance, require somewhat heavier foundations.

It will be noted that in these formulas for the vertical engine, only one-half of the material for the foundation is allowed, if compared to the horizontal motor of like character. This valuable property of the vertical engine is based on its action. As explained before, the foundation must counteract the movements imparted to the engine by the accelerating and retarding forces generated in the reciprocating parts. These forces act in the direction of the piston travel, and it is plain that in the vertical engine they tend to either lift the whole engine off the ground or to press it down into the ground alternately. As long as the combined weight of the engine and its foundation surpasses the lifting forces the whole system will remain stationary. This condition is easily obtained and the formulas give a liberal margin of safety.

Quite different and much more unfavorable is the case in the horizontal engines. Suppose the two types to be compared were exactly alike in dimensions and number of revolutions, then the free forces are also alike and they also work in the direction of the piston course. But this is a horizontal line considerably above the bottom of the foundation and its distance vertically is a very disagreeable leverage, and the momentum composed of the horizontal force multiplied with its distance from the bottom face tends to tilt the system alternately about the front or rear edge of the block. The smaller the vertical distance is, the smaller is the tilting force.

To counterbalance this tendency, the

momentum of the combined weights of the engine and block with reference to the tilting edge must at least be equal to the tilting momentum. The total weight may be supposed to be united in one common center of gravity. The distance between this point and the tilting edge, measured between verticals, is its leverage. The larger this distance is, or the longer the base of the block is, the better the weight is utilized.

While in the vertical engine the forces are caught directly in their line of generation and transferred to the ground equally by the total bottom face of the block, the horizontal engine sends out these forces in a line parallel to the supporting plane and they must be checked indirectly. Of course the ground is compressed most near the tilting edges of the foundation, while towards the center of the bottom face the pressure grows less and less. This is a very bad point and it accounts for the small stability and unsafe position of many foundations.

This condition is clearly visible at the end of the engine cylinder that shows a distinct jerk at every explosion. Often this is blamed on the engine, its design being called not rigid enough. The constant rocking motion causes the ground to be crushed and pressed away gradually and the fault grows worse in the course of time. Thus the train of troubles described in the beginning of this paper is started.

In consideration of these dangers, double the weight for the foundation is demanded in the horizontal engine, and the weight must be distributed carefully according to the rules laid down here if it is to perform its duties properly.

The center of gravity of the foundation block should be as low as possible. The required volume of the material should not be gained by the height of the block, but rather by its width and length. No part of the engine should project beyond the bottom face of the block. On the contrary its outline should inclose the whole engine with a liberal margin. This is especially important for the flywheel.

Only by a wide bottom face and a low center of gravity is the desired stability obtained. The size of the bottom face depends on the total weight of the foundation and engine combined, and the quality of the ground. The load on the ground should not exceed 14 pounds per square inch on soft clay or fine wet sand; 30 pounds on loam, dry, clayey sand; 40 pounds on common natural ground; 45 to

60 pounds on hard clay or dry sand; 70 to 80 pounds on dry, rough sand and gravel; 60 to 75 pounds on hard pan.

Thus the conditions of the bottom must be studied carefully in order to determine the proper dimensions of the foundation. Solid rock and natural stony earth are a safe building ground, and so are dry sand or gravel, dry loam or clay, if the layer is about 15 feet thick. Thin layers of loam or sand, shifting sand, wet sand, marl, humus, must be called an unsafe ground. Very unsafe are bogs and swamps, peat, and such places that have been filled in with earth and rubbish.

An unsafe ground must be fastened artificially. In principle this is done by providing a rigid connection between the solid substance lying beneath the unreliable layer and the bottom of the foundation. This connection is obtained by driving piles through the soft stuff till they find a solid hold in the hard bottom. For piles the trunks of oaks, firs or other suitable trees are used. The straight timbers are smoothed and preferably impregnated with some antiseptic liquid, to prevent rotting. The lower end of the pile is provided with a pointed iron ring. Their diameter is from about 8 inches up, their length varies from 15 to 25 feet, according to the requirements. Piles are generally driven in by machines. They are set in rows about from 2 to 4 feet apart over an area somewhat larger than the intended size of the footing. The tops of the piles are sawn off about two feet below the water level. Stout square timbers fastened onto the piles form a grate, which is covered with a floor of heavy boards. All the woodwork is rigidly fastened by strong nails and clamps. It must remain below the constant water level. On the platform is spread a volume of concrete about 2 feet thick that serves as a footing for the foundation. When the footing is thoroughly set, the foundation is built in the usual way. Pile foundations are only called for in quite unreliable locations, especially if the ground is quite wet and doughy with an inclination to flow. They are very costly owing to the amount of labor and material required.

On thin layers of otherwise fairly good ground with a possibility of yielding sideways under pressure, the load must be distributed over a large area and reduced to a low figure per square foot. This might be done by making the bottom of the foundation correspondingly large. But as concrete in a thin layer cannot be exposed to bending strains, while a thick body weighs too much, a grate must be constructed.

The bottom of the pit is first leveled carefully. Stout timbers, roughly finished and about 11 or 12 inches square, are laid parallel on the bottom 5 or 8 inches apart. The spaces between them are tamped with concrete, mixed as follows. One part of Portland cement, 1 part of slaked lime, 6 parts of well washed, sharp, rough sand, broken stones or clinkers, about one inch thick are thoroughly worked together with little water, to make a stout mass. The various stuffs are measured by volume. When the grate is set sufficiently a platform of boards at least 3 inches thick is nailed on and the foundation erected on some.

As the gas engine is entering more and more even the residence quarters of the towns and cities and comes in closer contact with human habitations, the problem of avoiding, or at least rendering harmless, their vibrations and suppressing the noises caused by the machinery, has demanded serious attention, much study and experiment. Elastic materials interposed between the vibration generating machine and the parts to be protected are considered the best solution.

Rubber, cork and felt are used at present. Rubber is extremely expensive. It has not yet been in use sufficiently long to judge about its durability. Its elasticity is well known and makes it well fit for the purpose. The rubber must be pure, the pieces should be at least ½-inch thick and the load should not exceed 150 pounds per square inch. It must also be protected from oil carefully. The use of rubber is not economical, as the material is liable to degenerate soon by atmospheric or chemical influences. It becomes either brittle or quite soft and soon fails to fulfil its duty.

By many authorities crude cork in its natural condition is considered an excellent insulating material. The cork is cut in strips of equal thickness that are pressed in iron frames and thus form plates of suitable size and shape. Owing to the air-filled pores the cork retains its elasticity for any length of time, and it does not rot. Felt or similar artificial fabrics willingly absorb oil or water; they harden and lose their elasticity.

By a patented process a German firm produces felt insulating plates that avoid these disadvantages and have proven their good qualities by more than 10 years of practical use. This felt is made of pure hair, impregnated with an antiseptic mineral grease and pressed hydraulically into plates ¾-inch thick. The top face is hardened chemically, the bottom is coated with a protective paint. The plates are furnished for loads between 350 and 420 pounds per square inch, while a pressure of 7,000 pounds per square inch does not destroy their structure. The chemically hardened surface increases the carrying capacity considerably. It is oil and water proof, withstands the abrasing action of the elastic movements and does not permit indentations and incisions by sharp edged machine pedestals and the like. The impregnation also prevents the entrance of humidity, keeps vermin away and avoids rotting. Its action is supported by the protective paint of the bottom face. The price is pretty high on account of the expensive crude material. The plates are furnished cut to the desired size and are charged for at the rate of $1.16 per square foot at present. It weighs 2.53 pounds per square foot. In order to obtain favorable results certain rules in applying the insulating material must be observed. See Fig 4, page 21.

Whatever insulation be chosen, it must be placed below the foundation block and the bolts must not pass through it. The load must be distributed evenly, compressing the surface uniformly at each jerk of the engine, and utilizing the elasticity of the material throughout. Below the insulating layer (7) a perfectly smooth and nonyielding bed (8) of concrete, finished with cement, must be provided; this is a very important condition. Why the insulation must be placed below the foundation is easily explained. The engine is bolted rigidly to the block, both forming one heavy, solid piece and both partaking of the vibrations originating in the engine. These vibrations are reduced considerably; they are strongest near the center line of the cylinder and scarcely perceptible at the bottom of the block. Here the little movements are conveyed to the surface of the insulating plate and easily consumed by its elasticity.

If, however, an insulation is placed between the engine frame and the foundation, as often enough is done, it cannot work properly and no good results can be obtained.

In this faulty arrangement the rigid connection between the engine and the block is interrupted, as the nuts of the bolts cannot be tightened thoroughly. Thus the foundation does not partake of the vibrations, as these cannot be sent through the loose bolts. The block then remains stationary and useless, while the engine undergoes the movements in full force. In consequence the insulation is soon ground to dust and the bolts must be tightened continually. If the insulation were removed entirely less trouble would be experienced.

An existing foundation can not be improved by placing an elastic layer on top, as far as the vibrations are concerned. The insulation will only reduce the noises of the motor a little.

About the foundation block an air space (9) 3 or 4 inches wide is left. It is covered by boards (10) in order to prevent it from being filled with dust and rubbish and to avoid accidents.

If an engine is to be placed on an upper floor of the building the location must be studied carefully, concerning the carrying capacity of the floor, the position of the beams or channels, also the strength of the adjoining walls. Though the motor is generally placed on an iron subbase having a large bottom face, a foundation of ample weight should be provided, as the only means to lessen the destructive action of the vibrations. The area necessary for the foundation is calculated to load the floor to only three-quarters of its carrying capacity. The floor is first leveled carefully, then an insulating layer is spread and on this heavy boards are laid. On the boards the concrete foundation is erected.

Another way is to construct a so-called hanging foundation. Thereby the bulk of the block is laid below the floor. A rectangular framework of box shape is constructed of L or I channels and forms a rigid skeleton for the concrete block. The top channels are longer, their ends rest on the beams of the floor. If one of the latter passes the foundation a clearance is left in the concrete. Between the supporting ends of the frame and the channels of the floor the insulating plates are placed.

Especially difficult are foundations on concrete floors. These are very elastic on account of the steel channels entering in their construction, and the vibrations of the engine are multiplied. Even small engines may cause an unbearable trembling of the floor. The noises are also much increased. Only by the addition of some substance, as heavy channels or cast iron columns reaching down to solid ground may matters be improved. Thereby the length of the vibrating channels is reduced and the size of the elastic deformations decreased in proportion, while the load is transferred directly to the earth.

Concrete floors and ceilings are very sonorous, it being practically impossible to suppress the noises of the machinery. In rooms of this description the hammering of the electric igniter and the cams or the noise of the air suction or of a leaky joint in the exhaust pipe may become a regular nuisance. By some attention and careful adjustments these noises may be removed or at least diminished. The engine, as well as the other machinery, should be well balanced and as noiseless as possible in their action; insulations should be interposed wherever a vibrating part touches the floor, ceiling or walls of the room.

No doubt the best plan is to avoid installations of gas engines in the upper stories, or if there is no other possibility, to use a well-designed vertical motor, to place its foundation close to a supporting wall and to apply insulating materials of approved quality liberally as explained before. Quite often engines are directly coupled to the driven machinery, notably to dynamos, pumps, compressors, hoists, compensate for little inaccuracies, will sometimes not do much good.

Conditions are improved if for each machine at least two smooth iron bars, either cast iron slabs or angles or channels, are carefully adjusted, grouted and rigidly fastened on the foundation. The bars are laid about flush with the top of the block, and to them the frames of the machines are bolted by well-fitting cap screws and secured by powel pins. If once properly assembled in this fashion the unit will stay in good shape. On the other hand, if taken apart, it can easily be fitted again correctly.

In concluding the present discussion the author believes he has shown that engine foundations, though apparently a somewhat dull subject, are yet worth some study.

As a gas engine plant can only be made a perfect success if every part performs its duties fully, the foundation must also be appreciated according to its high importance.

CONCRETE FOUNDATIONS.

H. M. NICHOLLS, M. E.

Has it ever occurred to the practical man the the gas engine is a power-transmitting machine? That it is designed to replace to an enormous degree the steam engine? I have been working steam, figuring steam, sitting up with steam, trying in every conceivable practical and theoretical way to reduce the cost per horsepower. In a way I have succeeded, but I am frank to confess it often is discouraging.

A copy of a gas engine magazine accidentally fell into my hands, and, always wanting information in any and all branches of engineering, I thought I would take it home with me and read it. I ran across things in that paper that made me sit up and take notice. I guess my mind was in a receptive condition, having been up against problems of economic operation. I never stopped with that single copy. I can't get enough gas engine; it has become a daily diet. The possibilities just unfold themselves so fast that it is astounding. The future is before it. It needs brains to work it out.

In talking gas engine to me an engineer said: "Why, Nicholls, we are just beginning." I don't believe truer words were ever uttered.

It is always a pleasure to hear or see a new idea; it's the ideas that form the nucleus of achievement. If you have any good idea, don't hide it away in the little cell where it generated, but be big enough and broad enough to give it to the world through the columns of a practical paper, where it may grow and do some good.

I have had considerable experience in all kinds of concrete foundations, and I grasped this opportunity with pleasure, feeling I might help some one in foundation construction, probably a brother who doesn't know his own mind. In this article only the fundamental principles of concrete foundations will be dealt with, but later I propose to advance some ideas in concrete foundations for gas engines which will be a departure from all previous construction. It will be given for the good of the cause, and I want to hear from men who are alive to the needs of gas engines.

Economy, simplicity and efficiency are, or should be, the requirements of any foundation. A foundation economical as to first cost, simple in construction and efficient as a machine base, one that can be made by any mechanic who has charge of an engine, is what will be described here.

The best is not always the cheapest, but in a foundation for a gas engine there is nothing better, nothing cheaper, nothing more practical than concrete. I will not make a statement that is not backed by plain facts, and the man who tries to put in as good or better foundation of some other material will find them plain, stubborn facts. In this day, when the cost of production is becoming a problem, it is up to us to make good in every branch of engineering and at every possible opportunity grasp and hang onto an idea that is fundamentally economical. There is money made where there is money saved.

Gas engines are gaining ground on steam. Why? It's because the germs of economical production are busy. Let them work overtime, try to cultivate the acquaintance of the microbe. It is only quack M.D.'s of mechanics who taboo the idea.

Every practical man in charge of a power plant, large or small, should have pigeon-holed in his brain for some future use, or in all probability immediate use, how to build a concrete foundation. Then if called upon tomorrow, the knowledge would be at his finger tips, and the foundation that would go in would be of concrete, and the possession of the knowledge would eliminate the needless expense and very probable delay of erection that would be occasioned if it were made of brick or stone or were you compelled to hire outside men.

When the location is decided upon, or should the location depend upon already existing circumstances and conditions, everything, such as fittings, piping, pulleys and line shafting, should be given careful consideration before construction begins. If for driving a main shaft, care should be taken that the angle of the driving and driven pulley is not too small. Now is the time to begin lining the engine up by excavating at right angles with the main shaft. So stake it out with perfect alignment uppermost in your mind.

With all gas engines the makers send free on request foundation plans and specifications. But the conditions of the ground must govern the size of the excavation; that is to say, the area of the base. Loose, spongy soil and other circumstances must govern this, and, as follows in this article, step out the base a little larger for poor conditions, but if good, firm ground, such as clay, the maker's plans will suffice. If the work of concreting is commenced immediately after the excavation it is always best to be on the safe side, by bracing the walls every few feet. This may be done by setting a twelve-inch plank against the side of the embankment, and put a 2x4-inch brace against it. These may be removed as the form is set, and these braces will serve a double purpose when put back by holding this form in place, and also preventing a cave-in. Too much caution can not be exercised in this matter, because you want absolutely no loam or foreign matter of any kind in the mixture. However, the matter of a cave-in will also depend almost entirely upon the kind of formation and the size of the excavation. So again you will be called upon to use your own judgment. A glance at the embankment will decide this point; though if there is any surface water that runs into the excavation, this may be taken care of by digging a hole at the side of the footing, about six inches deeper, and a hand pump placed in it, or if there is no pump convenient, it can be baled out with a bucket. If all water is kept away from the foundation until the concrete is set thoroughly, much better results will be obtained. Always have the bottom of the excavation as level as possible, as this will give the best bearing for the bottom of the foundation.

The first foot of the excavation may be filled, using no form, letting the concrete take the form offered by the earth. This is called in construction a footing, as it gives something on which the form may be set and leveled up and then braced. This footing is subjected to a compression force only, and does not have to be so rich as the remainder. A mixture of 1—3—6 or 1—3—7 will do.

The form for a foundation serves two purposes. First, it holds the soft mass of concrete in the desired shape until it has set, and, second, it preserves the richness of the mixture. Concrete, to give the best results, must, after being thoroughly mixed, show an inclination to flow, and in this state, unless a form is used, much of the richness will be lost, being taken up by the earth.

An expensive form is not what is required; something that will serve the two purposes just mentioned, any old lumber that happens to be stored around the place will suffice. More care should be taken with that portion that comes above the floor level, as this surface must be smooth. Therefore, whenever it is possible, select for this part surface stuff, and keep all joints tight. This will give a

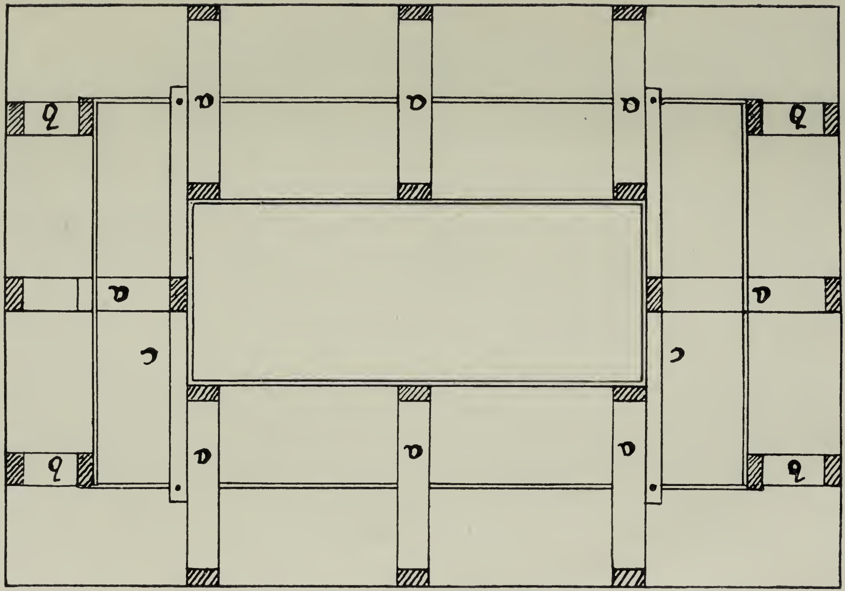


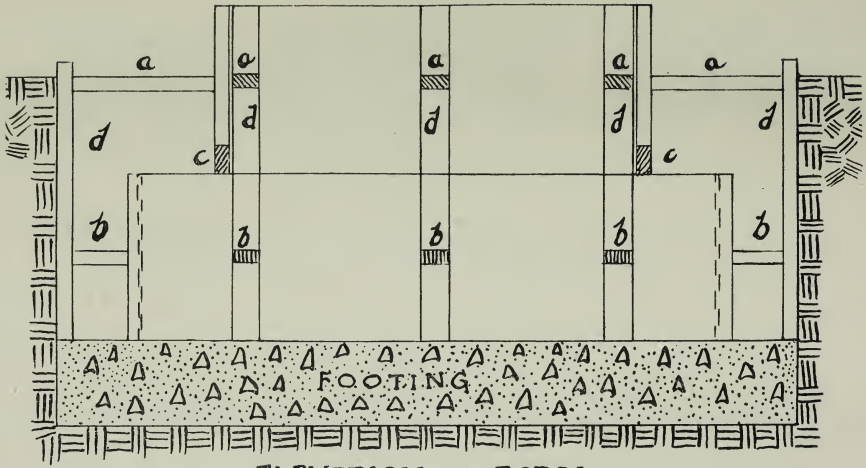
FIG. 1. PLAN AND FORM.

smooth finish that will be pleasing to the eye.

In Figs. 1 and 2 the plan and elevation of a form are shown, which gives a general idea of how the bracing and setting may be done. This is only to bring out the general construction, and does not necessarily have to be followed out to the letter.

Do not think that just because the form is to be used only for such a short time it can be set anywhere and in any manner. It must be well set, to the proper level, and be securely braced. In the form shown the larger box may be set first and braced by 2x4-inch pieces, indicated by small letters "b" and "d." The pieces "d" may extend to the top of the excavation. so that the braces "a" of the top box will be given a good base. The long braces "d" then form a bulkhead that prevents a cave-in, besides bracing the form. To prevent tht top of the form dropping down into the lower part and to hold it in place, two pieces "c," Figs. 1 and 2, are nailed on the lower part of the top box, and then it may be placed and fastened in the desired place.

The form should be at least three inches larger than the base of the engine on all sides, and should be filled to about one-half inch from the top of the form.



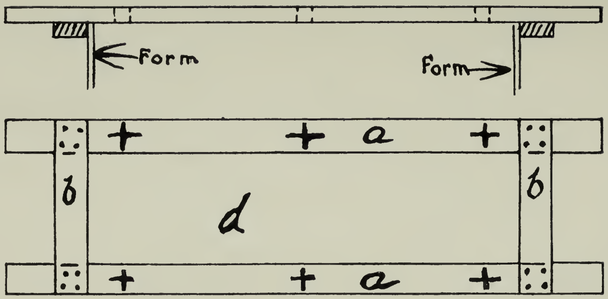
ELEVATION of FORM
Fig. 2.

This much should be allowed for leveling and grouting the engine in place.

The template may be made from the plan sent by the maker or taken directly from the base of the engine. It should consist of a light, but strong frame, securely nailed, so it will stand handling without getting out of square. Make it long enough so the ends may be nailed to the form after it is placed.

Fig. 3 shows a simple and good construction for a template. After the frame is made mark off on "b-b" the center line "d" and bore the holes in "a-a," measuring from this line. Always work from the center line, and lots of errors will be avoided. The short pieces "f-f" may be placed so that they just fit over the outside of the frame. This arrangement and a few nails will hold it firmly in place and in absolute alignment with driven pulley.

The foundation bolts may be handled several different ways. but I have found it the best practice, and would advise in foundations for small machinery to hang them from the template. The regular cast iron washer for foundations giving a good bearing surface, is always the best. Sometimes the regular O. G. washer is used. This gives the bearing; yet if by any chance the bolt should become loose



TEMPLATE FIG. 3.

and turn in the foundation, it would necessitate considerable trouble and expense to repair. The safe way is always the best, and unless you can get the regular foundation shown in Fig. 4, would suggest either of the two ways shown in Figs. 5 and 6.

Fig. 5 shows a foundation bolt with a 6-inch bend, which, when embedded in concrete, will prevent any turning.

Another plan, Fig. 6, which I am free to confess is a favorite with me in foundations for engines of 50 H.P. and less, is to have the foundation bolts made with an eye, and after they are hung pass a ½-inch iron rod through the eyes. This will overcome any danger of turning, and give a good bearing, besides.

On each foundation bolt there should be a sleeve of some kind, either made of some light wood or pieces of gas or galvanized pipe. These sleeves may extend part way down. I prefer the latter, as shown in Fig. 4. The reason is this: You want as perfect a bond between the concrete and bolt as is possible, and at the same time allow for adjustment and alignment of the machine. This construction, with the length of the sleeve two-thirds the length of the bolt, will give both bond and adjustment, and I would advise its adoption. The sleeves may be

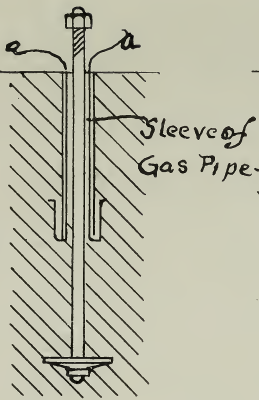


Fig. 4

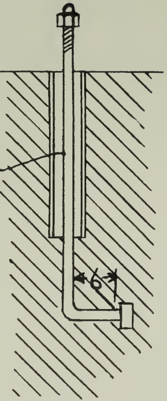


Fig. 5

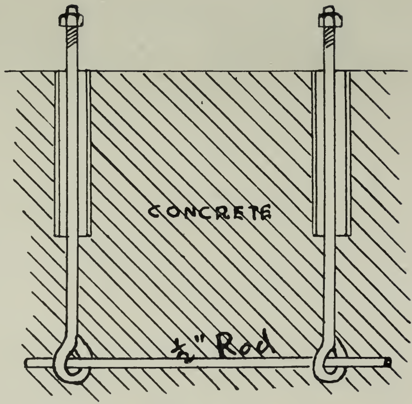


Fig. 6

FOUNDATION. BOLTS.

hung close under the template by wire hooks "a-a" Fig. 4. Make the holes in the template large enough to accommodate the bolt, and at least two of these hooks. The form will be filled within one-half inch of the bottom of the template. This will leave the sleeve too high to allow it to fill up with cement when grouting the machine in place. A slight tap will drive it down to the proper level, but this must be done before the concrete sets. I find this better than hanging the sleeve one-half inch below the template, for the reason that it is liable to be knocked from one side or other in throwing the concrete into the form.

For ⅞-inch or below 1-inch bolts use 2-inch pipe.

For 1¼-inch or 1½-inch bolts use 3-inch pipe.

The length of the foundation bolts will depend upon the size of the engine, and can be determined from the maker's plans. Having made the template where the bolts go through the same thickness as the base of the engine, all that is necessary is to take a full nut and a half above the template in hanging the bolts.

Figs. 7 and 8 give the elevations of a finished foundation in outline. For engines over 15 H.P. would suggest this plan be followed. Instead of a straight

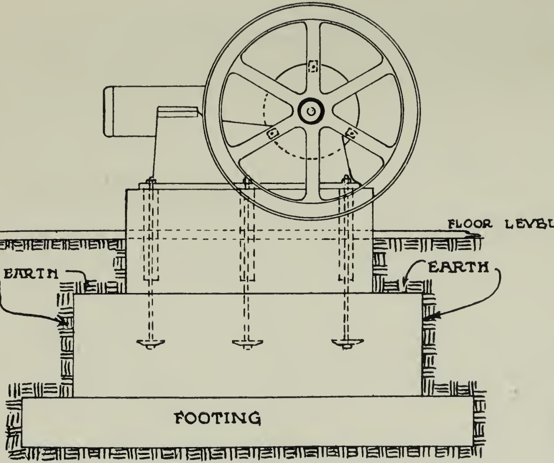


Fig. 7

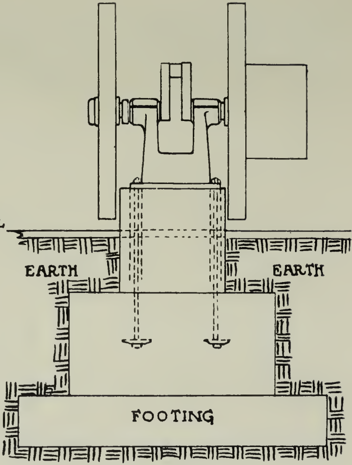


Fig 8

FOUNDATION

batter from top to bottom. let the batter begin below the floor level, about a foot, and at this point step the foundation out one foot and down two feet, and so on as deep as it goes. The reason for this is that it gives an opportunity of the upward as well as the outward bearing of earth, which makes the foundation more stable.

For foundation work I have found that a mixture of 1—3—5 of a good, medium setting Portland cement, clean, sharp sand and crushed stone or gravel, to be the best and most satisfactory mixture. Mix the sand and cement dry, turning it over twice before adding the stone. Then the whole should be turned twice, adding water enough to make the mixture show an inclination to flow. The mixture must be very soft in order that it may be properly worked. By properly worked is meant that all around the form the mixture should be tamped with a shovel and tamping rod; the shovel will work the finer particles to the outer edge of the foundation. Special attention should be given to this, as the finish of surface depends entirely upon how the concrete is worked and tamped. For a better finish a wash of cement and water, applied with a broom or large brush. is all right and makes a very nice finish, and this finish will take any paint nicely. An engine in dark red, resting upon a foundation of dark green, is the embodiment of good taste in any engine room.

Each maker has his own ideas in foundations and tries to make his foundation meet the requirements of his engine. Knowing that the builder knows the machine, or should know, better than the user, it is policy to follow out as near as possible the builder's foundation plan, making only necessary changes to suit existing conditions and requirements.

There is so much in concrete work and so little really known that there is a broad field for those interested. Every day adds many to the interested list. The farmer would want one kind of foundation for his engine that would run a corn sheller or churn. He would dig a hole where he wanted his engine, hitch up his team and go down the creek and get a load of sand and gravel mixed; drive back to the hole and use one bucket of cement and five buckets of his sand and gravel; mix it up with water and dump it into the hole. He has a foundation that will answer all of his requirements, and it cost him very little. That is a concrete foundation. Nothing expensive nor elaborate, but simple and efficient. If you happen to be a farmer, try it for your engine.

The village blacksmith would want another kind of foundation for an engine that would drive his grinding and drilling machines. He would have to build on a larger scale, and to meet more demands; but it would be concrete and as simple and inexpensive for his needs as the farmer's was for his.

The power man would want still another kind of foundation, one that would support an engine whose horsepower would be indicated by four figures. Yet he would have to stick to the same fundamental principles used by the former. It is like General Jackson's advice to his men: "Trust in the Lord, but keep your powder dry." Your foundation will give satisfaction, but you must watch your mixtures.

The engine should not be placed on its foundation until it is thoroughly set, and should not be run if not absolutely necessary for thirty-six to forty-eight hours, depending upon the kind of cement used in the concrete and the atmospheric conditions as to how quickly the mixture will set hard enough not to cause injury to the foundation.

For wheel pits, when below the sewer level or too low to drain outside of the building, shallow pits, fitted with sheet steel pans. can be used to good advantage; but if connection can be made with the sewer, put in a two-inch gas pipe. For the prevention of accidents a railing made of 1¼-inch pipe is very essential. This railing may be set in holes left in the concrete.

In leveling an engine too much care can not be exercised. First, secure some small wedges; these may be of hard wood or iron, if it can be made conveniently. Then with these and a spirit level the desired level adjustment may be reached by driving them between the base of the engine and top of the foundation. Level with center line of cylinder and crank shaft, if horizontal, and through the crank shaft and at right angles to it if vertical.

After leveling is completed and the engine is known to be in perfect alignment with the driven pulley, it may be grouted.

For a grout use one part sand and cement or one of cement and two of sand, mixed with water until it can be poured. Light pieces of plank may then be placed all around the top of the foundation, making a frame the height of the metal where the bolts go through. The grout is then poured into this until it is full; it may be worked under the engine by a piece of wire or small rod. Very little work will be required, since it will be nearly the consistency of water, and when it rises around the sides it will be known that the sleeves are full and the grout has reached the base of the engine. Finish filling the forms to the top of the lower part of the base; in other words, to the bottom of the nut of the foundation bolts. After the grout has set the frame way be removed. If the engine is small. and wooden wedges were used in leveling, the wedges may be left in, but if a large engine, where iron edges would have to be used, they should be taken out, so that there would be a uniform bearing and one that will equalize the strain throughout the engine. This is a very necessary qualification, as an engine will sometimes break itself on account of the unbalanced stress upon its parts.

Never tighten nuts on foundation bolts until the mixture used for grouting has set hard.

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